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Relationship Between Blood Pressure and Anthropometry in a Cohort of Brazilian Men: A Cross-Sectional Study

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BACKGROUND
Hypertension, a risk factor for cardiovascular diseases, and obesity are becoming a health problem in many developed and developing countries, as Brazil. Although hypertension and obesity are both closely associated, there is no universal anthropometric marker of this association. This is probably due to distinct population characteristics, and in the case of Brazil, the highly heterogeneous population. We evaluated which anthropometric measurement most closely relates to high blood pressure in a sample of Brazilian factory workers.

METHODS
A cross-sectional study was designed. In this study, multiple logistic regression and receiver operating characteristics analysis were performed in order to obtain the precise relevance of each anthropometric measurement as a blood pressure marker. Nine hundred and thirteen men, 36 ± 8 years-old, were submitted to a standardized questionnaire of demographic and risk factors knowledge, anthropometric and conventional blood pressure measurements were taken, and blood sample evaluations of glucose, total cholesterol, LDL-Cholesterol, and triglycerides were performed.

RESULTS
Overweightness or obesity was identified in 64, 11.1% were smokers and hypertension was detected in 29.2% of the participants. A linear correlation was significant ($P < 0.001$) between both the systolic and diastolic blood pressure and all anthropometric measurements, except for the systolic blood pressure and waist-to-hip ratio. Waist circumference (WC) was the only independent anthropometric measurement related to hypertension. Hypertensive patients presented all anthropometric measurements larger than normotensives.

CONCLUSIONS
Age and WC were the only independent predictors of hypertension, indicating that this simple measurement may be useful as a marker of hypertension in the Brazilian male, younger adult population.

Am J Hypertens 2009; **22**:980-984 © 2009 American Journal of Hypertension, Ltd.

Elevated blood pressure is a well recognized risk factor for cardiovascular diseases, like coronary artery disease, stroke, and heart failure. Obesity is an established health problem in many developed and developing countries.[1] It has long been recognized as closely associated with high blood pressure[2] although the mechanism is not clearly understood. The cluster of central obesity and hypertension is frequently associated with metabolic abnormalities in the so called "metabolic syndrome". Clinical trials have shown that weight loss is capable of reducing blood pressure.[3,4]

The body mass index (BMI) is the most traditional method for defining overweightness and obesity, but various measures of obesity, e.g., waist and hip circumferences, waist-to-hip ratio, waist-to-height ratio among others, have been employed to explore this relation.[5] The waist-to-height ratio is an emerging anthropometric measurement. It will change only when there is a change in the numerator (waist circumference (WC)) given that the denominator (height) remains constant in adults. A recent meta-analysis indicated that the waist-to-height ratio is a good discriminator of cardiovascular disease risk factors.[6] Much debate exists about the most adequate anthropometric measurement for detecting increased adiposity, especially in men, where abdominal fat accumulation may not be detected by many traditional indexes of obesity, like BMI.[7–9] There is increasingly evidence that the BMI and other anthropometric measurements may be even related to long term survival.[10,11] As there are regional differences due to socioeconomic and ethnical issues, it seems appropriate to expand the pool of available data for each part of the world to determine the best anthropometric method that can predict the occurrence of hypertension.

The purpose of our study was to evaluate which anthropometric measurement closely relates to elevated blood pressure in a sample of Brazilian factory workers.

METHODS

The study protocol was approved by the institutional review board of the Hospital das Clínicas da Faculdade de Medicina

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Received 29 September 2008; first decision 1 November 2008; accepted 8 May 2009; advance online publication 4 June 2009. doi:10.1038/ajh.2009.104

de Ribeirão Preto, University of São Paulo. A cohort of 913 men, workers of the same factory plant located in the city of Itu, in São Paulo State, Brazil, was evaluated. They were invited to participate during annual routine medical evaluation and no refusals occurred. All volunteers signed an informed consent.

A standardized questionnaire was applied to obtain information about the workers' previous medical history, use of medications, knowledge of cardiovascular risk factors, and demographic data.

Anthropometric measurements were obtained with the participants standing and wearing indoor clothes and no shoes. Their height and weight were measured with a daily calibrated scale. The anthropometric measurements were obtained according to the NHANES III protocol (http://www.cdc.gov/nchs/data/nhanes/nhanes3/cdrom/nchs/manuals/anthro.pdf). Overweightness was identified if the BMI ≥25 kg/m^2 and obesity was defined if the BMI ≥30 kg/m^2. The skinfold thickness was reported as the mean of three consecutive measurements of the subscapular, triceps, suprailiac, and abdominal skinfolds (Lange caliper; Beta Technologies, Santa Cruz, CA). Blood pressure measurements were collected using an automatic and validated blood pressure device (Omron–model HEM 705-CP) with the patient seated and after 5 min of rest. Three measurements with 1 min intervals were obtained and the mean value was used. The cuff size was selected according to arm circumference. Hypertension was defined if the mean pressure was ≤140 mm Hg for systolic blood pressure and/or 90 mm Hg for diastolic blood pressure, or if the patient referred to the use of antihypertensive medication.

Data analysis. Data are expressed as mean ± s.d. Pearsons' linear correlation with systolic and diastolic blood pressure were calculated, as well as Fishers' exact test to assess probability of association. Receiver operating characteristics curves were created in order to obtain the sensitivity and specificity of each as a blood pressure marker. Stepwise multiple logistic regression models including age, BMI, waist and hip circumferences, skinfolds and waist-to-height ratio, were performed to adjust for potential confounders. All variables were tested for normal distribution using the Kolmogorov–Smirnov test and were normally distributed, except when indicated. Parametric tests were applied and the level of significance was established as 5%.

Table 1 | Demographic, anthropometric, and clinical characteristics of participants

Sample number	913
Age (years)	36 ± 8
Height (cm)	1.7 ± 0.1
Weight (kg)	77.7 ± 13.1
BMI (kg/m^2)	26.7 ± 4.0
BMI category	
Underweight (<18.5)	0.7%
Normal (18.5–24.9)	34.9%
Overweight (25.0–29.9)	47.0%
Obese class I (30–34.9)	13.9%
Obese class II (35–39.9)	2.6%
Obese class III (≥40.0)	0.9%
WC (cm)	92.4 ± 11.4
Hip circumference (cm)	101.7 ± 8.6
Waist-to-hip ratio	1.05 ± 0.13
Skinfold thickness (mm)	
Subscapular	20 ± 7
Triceps	15 ± 7
Suprailiac	17 ± 8
Abdominal	30 ± 14
Systolic blood pressure (mm Hg)	130 ± 15
Diastolic blood pressure (mm Hg)	79 ± 12
Hypertension category	
Normal	23.3%
Prehypertension	46.7%
Stage 1 hypertension	23.4%
Stage 2 hypertension	6.6%
% Smokers	11.1

BMI, body mass index; WC, waist circumference.

RESULTS

Characteristics of the participants

Table 1 summarizes the demographic and clinical and anthropometric characteristics of the participants. Overweightness or obesity were identified in 64% of the participants and hypertension was detected in 29.2% of the participants and nearly half of the sample was in the prehypertension stage. No participant was previously on medical treatment for hypertension.

Blood pressure and anthropometry

Linear correlation was significant (P < 0.001) between both the systolic and diastolic blood pressure for all anthropometric measurements, except for the waist-to-hip ratio, that was not normally distributed, and varied between 0.22 and 0.39 as seen in Table 2.

A consistent increase in the systolic and diastolic blood pressure could be observed with increasing WC and BMI when these measurements were analyzed in quintiles, except for waist-to-hip ratio that presented an initial increase in both blood pressure levels followed by a reduction in higher values.

The participants with a WC above 94 cm had higher systolic (137 ± 15 vs. 128 ± 15 mm Hg; P < 0.001) and diastolic (86 ± 11 vs. 77 ± 11 mm Hg; P < 0.001) blood pressure than those with a WC below 94 cm. Similar features could also be identified for the BMI. The overweight participants had higher systolic (133 ± 15 vs. 124 ± 14 mm Hg; P < 0.001) and diastolic (82 ± 12 vs. 73 ± 11 mm Hg; P < 0.001) blood pressure than those with a BMI below 24.9 kg/m^2.

A WC below 94 cm and a BMI below 24.9 kg/m^2 yielded a negative predictive value for the presence of hypertension in 80 and 85%, respectively. The skinfold measurements correlated with conventional blood pressure measurements, especially

Table 2 | Linear correlation coefficients between anthropometric indices and systolic and diastolic blood pressure

Anthropometric measurement	Systolic blood pressure	Diastolic blood pressure
BMI	0.33*	0.39*
WC	0.34*	0.39*
Waist-to-height ratio	0.31*	0.37*
Skinfold		
Triceps	0.11*	0.22*
Subscapular	0.22*	0.31*
Suprailiac	0.19*	0.28*
Abdominal	0.19*	0.24*

*$P < 0.001$.
BMI, body mass index; WC, waist circumference.

Table 3 | Differences in age, blood pressure and anthropometric indices among participants according to the presence of hypertension

	Normotensive ($n = 646$)	Hypertensive ($n = 267$)	*P*
Age (years)	35.2 ± 8.0	37.7 ± 9.1	<0.001
WC (cm)	90.2 ± 10.4	97.6 ± 11.9	<0.001
BMI (kg/m^2)	26.0 ± 3.7	28.4 ± 4.2	<0.001
Waist-to-hip ratio	1.1 ± 0.1	1.0 ± 0.1	<0.014
Waist-to-height ratio	0.53 ± 0.06	0.57 ± 0.07	<0.001
Diastolic blood pressure (mm Hg)	74 ± 9	90 ± 10	<0.001
Skinfold (mm)			
Subscapular	18.9 ± 6.7	22.4 ± 7.9	<0.001
Triceps	14.5 ± 6.5	16.5 ± 7.4	<0.001
Biciptal	10.1 ± 5.2	12.3 ± 6.9	<0.001
Suprailiac	16.5 ± 7.0	19.5 ± 9.2	<0.001
Abdominal	28.5 ± 13.4	33.5 ± 13.8	<0.001

BMI, body mass index; WC, waist circumference.

Table 4 | Stepwise multiple linear regression of anthropometric indices related to the presence of hypertension on univariate analysis

	Odds ratio	95% CI	*P*
Age	1.03	(1.01–1.05)	0.01
BMI	1.05	(0.94–1.16)	0.39
WC	1.07	(1.03–1.11)	<0.001
Hip circumference	1.02	(0.98–1.05)	0.36
Triceps skinfold	1.00	(0.97–1.03)	0.95
Biciptal skinfold	1.01	(0.97–1.05)	0.60
Subscapular skinfold	1.02	(0.99–1.05)	0.24
Suprailiac skinfold	0.99	(0.96–1.02)	0.54
Abdominal skinfold	1.00	(0.99–1.02)	0.92
Waist-to-height ratio	0.006	(0.00–1.20)	0.06

BMI, body mass index; CI, confidence interval, WC, waist circumference.

for the diastolic blood pressure, and the central ones presented better correlation values compared to the peripheric (triceps) skinfold (**Table 2**).

Hypertension and anthropometry

Among the participants, hypertension was detected in 267 (29.2%). **Table 3** summarizes the differences between the hypertensive and normotensive participants.

The WC and BMI had similar results in the receiver operating characteristics analysis (0.68; $P < 0.001$). Among skinfolds, subscapular was the one with the highest receiver operating characteristics value (0.63, confidence interval (CI): 0.59–0.67; $P < 0.001$).

In order to assess the influence of age and anthropometric variables, a multiple logistic regression analysis model was computed. As shown in **Table 4**, age and WC were the only independent predictors of hypertension.

DISCUSSION

In this cohort of adult men, with a relatively young age, we observed that the blood pressure increased with higher BMI, WC, and various skinfold locations. The relation was linear and no threshold was noted. Multivariate analysis identified that only age and WC were significantly associated with the presence of hypertension. Another important finding was the elevated prevalence of overweightness and hypertension. There is a large variation in overweightness/obesity prevalence in Brazil, mainly due to its regional inequalities, ranging from 15 to 54%,[12–14] and our population presented one of the highest levels.

The "metabolic syndrome" diagnostic criteria include both elevated blood pressure and WC above 102 cm,[15] an association that seems to be frequent in the over weighted strata. There is some evidence that the mechanism of obesity-associated hypertension is related to inadequate vasodilatation of blood vessels in response to increased intravascular volume and cardiac output, an effect related with an increased sympathetic nervous system tone and insulin resistance. So, in a group of overweight individuals, higher values of blood pressure are expected.

Few studies have explored the relationship between a large set of anthropometric measurements and blood pressure in the Brazilian adult population,[16–19] as well as in other parts of the world.[20,21] A positive association between WC and BMI, similar to other studies,[8,22–25] and blood pressure was noted. This association occurred for systolic and diastolic blood pressure. Benetou *et al.* identified in the European Prospective Investigation into Cancer and Nutrition population that below 55 years of age both anthropometric measures behaved in a similar fashion, but for those beyond that age, WC was a better marker for men and BMI for women,[26] a feature we were unable to explore due to the characteristics of our population.

In our population a positive association could not be demonstrated with respect to waist-to-hip ratio, as previously reported in some studies,[17,22,27] but not all.[26,28] This may be explained by the fact that our population consisted only of men, and some previously published studies did not analyze the influence of waist-to-hip ratio by gender. Also, hip measurements include not only fat tissue but muscle and bones, that can present distinct proportions due to the physical activity involved or aging.[22] In fact, a large hip circumference has been associated with overall health and longevity.[29]

Among skinfolds, subscapular thickness presented a very good positive association with blood pressure measurements. This association has previously been described in an Italian male population,[30] and our results are similar. It probably reflects the amount of fat tissue centrally located. On the other hand, studies that used ambulatory blood pressure monitoring failed to demonstrate such association[31] and is a matter for further research. In the multivariate analysis, no skinfold was identified as an independent predictor of hypertension.

WC was the only independent predictor of hypertension in our population besides age. Age is well recognized as related to hypertension. In our sample age distribution was narrow, and may explain its small influence. Some previous studies showed that WC had the strongest association with blood pressure, but only specific and homogeneous populations were evaluated, like lean Asians,[32] white Americans,[33] or Europeans.[30,33] The Brazilian population is highly heterogeneous in its genetic composition due to a long history of miscegenation between portuguese settlers, african slaves and native americans. Also, regional inequalities, especially economic, are extreme. In Brazil, parts of the country present a per capita income close to developed countries and others equal to some underdeveloped nations. This latter factor may influence the food pattern of the population. So, it may behave somehow different from other groups. WC has been also reported as the only marker of adiposity associated with ambulatory blood pressure monitoring, a well validated tool to identify hypertension.[31]

The advantages to using the WC as a tool to be used in screening programs in developing countries like Brazil are straightforward. There is a need for a simple and unique measurement, using an inexpensive tool, that requires no calculations. Evidence for using a waist-to-height ratio is becoming available in various scenarios[34–36] and a recent meta-analysis indicates that it may be a better indicator for cardiovascular risk factors like hypertension,[6] but further research is needed. It may correct some incongruence that results from individuals with different heights and the same WC. The same tool for both measurements may be used. In our group, the waist-to-height ratio was not an independent predictor, probably a consequence of the low height variability.

Our study has several limitations that warrant recognition. First, its a cross-sectional study. Second, only men were included in the analysis due to the fact that ~10% of the working force of the plant consisted of women not included in this study, and thus may not be regarded as representative of the general population. Third, only a single visit was used to obtain blood pressure. Although all care was taken to obtain measurements using all recommendations to minimize interference, misclassification may have occurred. Finally, in order to explore the possibility of colinearity, even though we used logistic regression models, we calculated the variance impact factor using a linear regression model of all the covariates of interest. Incremental models were applied to try to identify any change of direction that could expose colinearity without success. The resultant variance impact factor was 8.8, less than the recommended value of 10 for this factor.

In conclusion, WC, a simple and inexpensive anthropometric measurement, may be useful as an assessment tool of the risk of hypertension in the Brazilian population. It may be used in screening programs and further longitudinal studies are necessary to validate and expand these results and its value as a prognostic marker, as well as the cut-off values that better fit.

Disclosure: F.N. is speaker for Sanofi-Aventis, Daiichi-Sankyo and Novartis, and does research for Boheringer-Inghelheim e Sanofi-Aventis.

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